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An

Inaugural Essay

on the

Vacuity of the Arteries

after

Death

by

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of

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The Vacuity of the Arteries after death, is well known to prosecutors of Morbid Anatomy, and to Medical Men generally; but no satisfactory explanation has yet been advanced of this Phaenomenon.

In speaking of his experiments, Dr. Horlan says "I now thought that the Phaenomenon in ques-
"-tion was explained, by supposing the blood to circulate
"in the veins, whilst no more was propelled into the
"Aorta and arterial canals, the latter was of course
"emptied. — But I was soon convinced that though
"the principal objection was obviated, the experiment
"did not explain in what manner that portion of
"blood, forced into the aorta by the last contraction
"of the left ventricle, found its way independent
"of any "vis a tergo" through the whole extent of the
"arterial canals to the mouths of the veins. This
"constitutes the problem to be solved: and it was of
"this in particular Dr. Wistar asserted, he had

"never heard any satisfactory explanation offered;
"although he had availed himself of frequent oppor-
"tunities of conversing with men of science upon
"this subject; Some of whom argued the pressure
"and action of surrounding muscles, as the cause;
"others the pressure of the external air; but he
"remarked "the elasticity of the coats of the arteries
"would resist any such pressures, and prevent the
"obliteration of their calibres." Eclectic Repository Vol 9 th.

However interesting to the Physiologist and
to the Medical Practitioner, this subject of itself
might be, its importance is much increased when we
consider, how closely it is connected with the subject
of venous circulation.

As various powers have been assigned as causes
for the blood flowing from the extreme arteries back
to the heart, it will be proper to mention them,
and separately to take them into consideration.

1st. By Richerand, Venous Circulation is ascribed chiefly to the contraction of the veins themselves.

2nd. by Harvey, by Majendie and by Spalanzani, it is attributed to the action of the heart alone.

3rd. by Barry and Carson it is asserted, that Venous Circulation is owing to a vacuum formed in the chest; and by the latter of the two, that the vacuity of the arteries after death depends on the same cause

4th. While Bordeu, Bichat, and some others place the power almost exclusively in the Capillaries

Other Powers have also been assigned in aid of those above mentioned. Viz the action of Muscles, the elasticity of the arteries &c.

That Veins possess a contractile power is proved by their diminution in Calibre, when removed from the living body, as in the operation for

varicose vein; — by puncturing a vein between two li=
=gatures; and by the superficial veins assuming different
sizes, according as the surface is exposed to a warm or
a cold atmosphere

But this contractility is very little more than
sufficient to accomodate them to the quantity of their
contents, and is inferior in force to the power driving
the blood on from behind, hence the distension of a vein
on the application of a ligature, or on any other cause
obstructing the course of the blood; and hence
also the engorgement of the veins in death.

That the blood does not circulate in the
veins by their contractility, may be seen by the
following experiment.

Select that part of a superficial vein on the
arm or hand, where there is a space of one inch
or more between two valves, without receiving any
branch laterally: place one finger on the lower
valve, the vein then between the finger and the

upper valve remains full as before, which it would not do if the vein was the cause of the motion of the blood. Then with a second finger force what blood remains between the first finger and the upper valve above that valve. The vein being empty below and the blood still remaining above the upper valve distinctly points out its situation. Lastly raise the fingers and instantly the emptied portion of vein fills, showing that the motion of the blood depends on a "this a true"

Work was shown by the following experiment related by Majendie in his work on Physiology page 334 he passed a ligature around the thigh of a dog, without including the crural artery or vein, and then applied a ligature on the vein near the groin when he making a slight opening into the vein the blood escaped in a continual jet, he then pressed the artery between his fingers to prevent the arterial blood from reaching the member, the blood ceased

[illegible] on two accounts but not in many instances and on examination [illegible] which stopped through the whole length of the [illegible] joined the other untouched by [illegible] completely empty the heart of the [illegible] then stopped: at this period I removed to expose the artery, the blood [illegible] the heart [illegible] as if it had reached the last division [illegible] at the opening of the vein, the jet [illegible] ordinarily till the same [illegible]. It then compressed the artery again till it was emptied and then let the arterial blood into it during the flowing of the blood from the orifice of the vein took place but there was no jet till the artery was entirely free.

Since the attributes [illegible] to the heart differ sometimes amongst themselves: some [illegible] with the propulsive action of the heart, the [illegible] of the arteries: Others deny the heart acts

or the one hand as a propelling power or the other as an attracting by forming a vacuum by the dilatation of the right auricle.

However necessary the contraction of the left ventricle is to send the blood to the extreme arteries, yet that it is not necessary for venous circulation is proved by that going on after the impulse of the heart has been cut off by a ligature or by pressure applied on an artery; the circulation thus going on till the arteries become exhausted of their contents as in the experiment of Majendie. — Though Majendie inferred that venous circulation was owing to the propulsive action of the heart and the elasticity of the arteries (in addition he does not admit), yet I think a different construction might be put upon it, which will be mentioned hereafter.

With the view to ascertain the truth in this

Under the following experiment was made by myself with the assistance of a fellow student. We confined a full grown Cat on its back, with the legs extended horizontally; an incision was made into the Abdomen, and a ligature drawn tightly around the inferior Cava a little above the bifurcation: the inferior Cava was then punctured with a lancet just below the ligature, the blood flowed immediately and continued flowing, as we judged, between 10 and 15 minutes. In ¾ of an hours from the application of the ligature, the animal being dead, the Femoral and Tibelarian arteries were examined and found alike empty, the corresponding veins were loaded with blood.

Inference. As the blood flowed from the Vena cava and the arteries became empty after the impulse from the heart had been cut off. We must infer, there is a power independent

of the heart capable of propelling the blood into and through the veins: [illegible] the contractility of the veins, for the Femoral veins remained full although there was an outlet for the blood, by the opening in the inferior Cava.

That Venous Circulation depends on the heart, is also contradicted by the following experiment extracted from Spalanzani's work on the Circulation page 359. I placed (he says) a ligature "on the middle of the descending aorta of a Frog: "the portion between it and the heart increased in "capacity, and became a deeper red, whilst that "portion beneath the ligature was pale and collapsed, and although it retained only a small "quantity of blood, its diameter did not appear in "the least diminished."

That the heart attracts the blood by dilatation, and thus causes its motion in the veins, is contradicted by the common operation of Venesection;

by the experiment of Magendie; and by that made
upon a wall, in which a ligature was found around
the vein: It is also contradicted by the universal
venous engorgement that takes place after death

The opinion of Carson to which much attention
has been paid that the circulation of the blood in the
veins and that venous movement is owing to the
tendency in the veins to form a vacuum by their
motions, which in fact has the effect of draining
the blood from the different parts of the body until
this vacuum is filled. In which account it is
the arteries are found empty after death. there not
being blood enough to fill both arteries and veins.

This opinion has already been refuted in
the fifth vol. of the Philadelphia Medical Journals
by Evans. who met the observations of Mr. Carson
upheld Carson's experiments with an entirely different
result.

Carson killed some rabbits by opening the thorax, thus causing the lungs to collapse and the vacuum if any existed to be destroyed. In these rabbits he found the muscles red, bleeding on being cut, the transparent membranes much injected and the veins collapsed. While in rabbits killed by puncturing the spinal marrow the muscles were white and dry, the membranes not injected, and the veins turgid.

But in Dr. [illegible]'s repetition of these experiments, not the least difference could be perceived in the whole circulation between animals killed in the two different ways except the lungs of those killed by collapse were of a lighter colour and contained no blood; he found the venous system of different capacity to contain the blood independent of the vacuum formed in the lungs.

But Carson has not shown that a vacuum really existed after death. And by the following experiment

extracted from Dr. Williams's paper on the circulation of the blood in the Lungs, in the 13th. No. of the Journal of Foreign Medical Science. We see, that the circulation of the veins and the right side of the heart may go on after the chest has been laid open, and all vacuum of course destroyed.

"An Animal was killed by cutting the Trachea at the acme of inspiration, and the sternum and "cartilaginous ends of the ribs were removed, in presence of Dr. Traill. The blood in the pulmonary veins "was observed to change its colour to a darker hue as the current lessened. Immediately after the last stroke, "the left ventricle felt contracted: then an irregular "action of the muscular fibres of the right ventricle "commenced which lasted for some time. - By a "mistake, one of the branches of the pulmonary artery "traversing the right lungs was divided instead of "a branch of one of the pulmonary veins, which "poured out blood copiously. As soon as the mistake

discovered, the bladder was punctured in the presence
of an assistant. As he pressed the fore finger of the
right auricle and ventricle became greatly distended.
One of the pulmonary veins traversing the left
lung was now punctured, and a small quantity
only of blood oozed out. When the blood which had
accumulated in the left auricle and ventricle
was discharged by making a free opening into
the former of the two cavities. After it was discharged
no more blood flowed or oozed out of that opening,
or from the puncture that was in the vein.
For at the same time blood continued to return
regularly from the system at large, to the right
cavities of the heart. After a while the pulmonary
artery was punctured, which was followed by a copious
discharge of its contents. The windpipe was last
divided and the lungs instantly collapsed, with
considerable rapidity, until there was visible diminution
in their bulk had taken place. To satisfy

ourselves that the vessel that bled so freely was a branch
"of the pulmonary artery, a probe was passed into it
"from the right ventricle. After the action of the
"heart had ceased we were much astonished
"at the irritability of the diaphragm; producing repea-
"=tedly the most perfect contraction of that muscle:
"all the others were at rest"

Is this vacuum which is said to be accomplished, which
should the blood leave the arteries, remain a
vacuum then, in order to assist our breathing in the
chest. Now I do not consider there is a formed
vacuum in the arteries after death, and if possible
they are filled with the residue that escapes from
the blood when drawn into a vessel, or with
some other gas; but as much is also contained
in the blood about the [illegible] there would be
no chance to supply the deficiency there as in the
arteries.

And according to Carson's theory the arteries

should be equally empty after death occasioned by lightning as when occasioned by puncturing the spinal marrow; for the resiliency & elasticity of the veins and arteries, to which he attributes this phaenomenon, is as he acknowledges a property of texture and of course must continue long as that texture remains perfect. — But the arteries are not empty when death has been occasioned by lightning. The reason for which will be found hereafter.

When I assert that the emptiness of the arteries after death is caused by a vacuum existing in the chest, I do not deny that venous circulation during life is promoted by the vacuum, caused by the expansion of the chest in inspiration; this has been proved by Barry. — But still I cannot consider with him that this vacuum is the chief cause, — nor even the blood from the great veins in the neighbourhood of the heart, which become distended during inspiration.

I can not suppose that blood would not flow

from the Vena Cava after a ligature had been placed on it near the heart, or puncturing it above the ligature as in venesection. On Dr. Barry's hypothesis it ought not. But the blood does flow as has been before shown.

I have come now to the opinion of Dr. Darwin, Bichat and some others, namely. That Venous Circulation is owing, mainly to the action of the capillary vessels: an action the existence of which has been much questioned: and from the minuteness of the vessels, difficult to be discovered by the eye: therefore we are forced in some measure to reason from analogy.

That Capillary vessels are endowed with a power of propelling fluids, seems evident from the economy of Plants and Trees, they have no heart, yet a fluid is taken up by the minute capillaries of the roots, is conveyed a considerable height to

undergo the necessary change in the lungs, and from thence is conveyed, and deposited in other parts for the growth, for the reparation of injuries &c. But confining myself to the animal economy, and passing over the abdominal circulation, where the blood distributed through the arteries to the different viscera, passes then through minute vessels to a large trunk, is conveyed through the and minutely distributed in the substance of the Liver, then once more is collected into large vessels before it reaches the vena cava, in its way to the heart.

But passing over the abdominal circulation we have an instance in the Intestines of a tube propelling its own contents, even when they are nearly solid, by contractions obvious to the sight. In certain inferior animals also have no heart, their blood is circulated by the action of the vessels themselves. And it is to the same kind of action we must

arterial the flow of blood from the different secretory glands as the testes, the salivary glands &c. But in the lymphatics and lacteals the analogy is more striking; by them a fluid is taken up, conveyed by their own contractions a certain distance, notwithstanding the obstruction from the convolutions in the lymphatic glands, and eventually is emptied into the left subclavian vein. And this action of the absorbents continues after the contractions of the heart has ceased, as may be seen by examining the mesentery of an animal killed a short time after having been fed.

Substances also have been injected into animals, after they had apparently been dead, and were taken up by the absorbents, and discovered in other parts by chemical tests. Barry's experiments do not prove (as he thinks) that absorption depends upon atmospheric pressure; they only prove that the force by which Lymph is propelled, is inferior in degree to

the pressure of the atmosphere, and that when put in opposition to the absorbents, the motion of the fluids in these vessels is checked, or its course reversed.

That Capillary vessels possess a power of contraction is supported by the following facts.

"Instances occur, when from passions of the mind, "from a sudden great revulsion by blood letting, or convulsions, the blood has retreated from the smaller "into the larger arteries. And in like manner from "an obstruction being formed in the remote branches "above the valves, the blood has been known to "return into the extreme branches." Haller, page 31

Speaking of the blood in the Capillaries Bichat says "In the ordinary state, it moves generally in "an uniform manner from the arteries towards the "veins: but at every instant it may find causes "of irregular oscillations in its numerous anasto "moses: hence as we have seen the necessity of "these anastomoses. These irregular oscillations

"in the motion of the blood in the capillary system
"can be seen with a microscope. Haller, Spalanzani
"and others, saw them a hundred times. They
"saw the Globules advance, recede, move in many
"different directions, in animals with red and cold
"blood, when they irritated the mesentery, or any other
"transparent part." General Anatomy, Vol. B. page 3.

If then the blood can advance or recede
from a given point, by irritating that point, there
must be a power located there by which the blood
can be moved.

The powers assisting venous circulation, namely.
The Elasticity of the arteries, and Muscular action
no doubt have some effect; but that elasticity is
not the cause of their vacuity is evident; for though
empty that elasticity prevents their parietes from
coming in contact, hence they retain their calibre
after death. Nor is the action of the muscles in=

[illegible] [illegible], or the blood circulates in a [illegible] and in one [illegible]. The [illegible] advanced in support of the [illegible] of [illegible] [illegible] namely, the [illegible] [illegible] [illegible] may think [illegible] the swelling of the bellies of the muscles the deep [illegible] veins are compressed and then blood must seek a passage through the superficial veins.

But it is the chief cause [illegible] [illegible] after [illegible] without [illegible] [illegible] [illegible].

In speaking of Capillaries, I do not say whether there be a distinct set of vessels interposed between the arteries and veins; nor whether contraction exists only in the capillaries or the minute ramifications of arteries performing functions attributed to capillaries; or whether contraction also exists in arteries of somewhat larger size: but according to John Hunter it

does not exist in the venous or in the middle sized arteries to any extent. With this explanation I will still use the term capillaries.

If then the capillaries possess the power of propelling the blood into the veins: and if this power similar to that of the absorbents continues some time after the action of the heart has ceased it will be sufficient to explain the cause of the vacuity of the arteries after death, provided, there be some other power, by which the blood remaining in the arteries after the last contraction of the left ventricle can be presented to the mouths of the capillaries for them to act upon it.

This can not be the heart for there is no medium through which it can act, as it has ceased. It can not be the elasticity of the arteries for this keeps their parietes asunder preserving their cavities: nor can it be their contractility for this is denied to arteries of any size, or is inferior to the elastic power.

But there is another principle which operates on the blood in common with all other matter, viz. Gravity, but which so far as I know has never been applied to explain this phaenomenon.

That Gravity influences the motion of the blood in the veins of the human body is evident: hence an inflamed extremity is directed to be kept elevated, and hence also in wounds of the palmar arch, where it is difficult to take up the bleeding vessel, the effect in stopping the hemorrhage by keeping the arm raised to a position almost perpendicular. That gravity has an effect on the blood after death is evident, from that part upon which a dead body has been lying, becoming much injected, while the most elevated part is not.

This effect of Gravity is also supported by the following Experiments. "After having killed "several Salamanders by decapitation in order that

"the [illegible] [illegible] [illegible]. [illegible] and the
"to the head. [illegible] [illegible] to the [illegible] [illegible] [illegible]
"was instantly precipitated to the [illegible] extremity,
"but resumed its original situation upon placing the
"animal in a horizontal position. The blood
"likewise ascended towards the head, upon raising the
"salamander and descended into the vessels of
"the tail when I changed the position of the
"extremity. The middle sized vessels exhibited
"the same phenomenon upon [illegible] [illegible] [illegible]
"shewing the effects of gravity, but the circulation in
"the smaller branches seemed to be little influenced by
"this law." Spalanzani on the circulation page 35.

"Such was the position of the two umbilical
"arteries of these eggs two days after incubation that
"the power of Gravity could not be contrary to one
"without being favourable to the other. Whilst the
"blood scarcely moved in the first of these vessels
"it had in the second a rapid and uniform

"Bourse" page 384.

"The blood of all animals is mixed with the principle of Vitality, it is heavier than Lymph, & Pale and whatever be the position of the organs in a dead body, it accumulates by its own weight in the most dependant parts. the same phaenomena were observed by Haller in Moribund Frogs.

Spallanzani page 384

"may be asked why the most dependant parts of a dead body remain injected, If the circulation of the blood after apparent death, is owing to the action of the capillaries. This may be explained by the supposition, that the organic life and action of the capillaries has become so far exhausted, before the blood has ceased flowing to their mouths, that they are unable to propel the last portions.

If we may suppose that the proportion transmitted by the most dependant capillaries is too great for the capacity of the corresponding veins: Consequently

to coat pulmonary blood must accumulate at the commencement of these veins. And further, the injection or dark colour of the most dependant of the death, is owing partly perhaps also to the exhalation of blood, or its percolation into the spongy tissue of the part.

From what has been said, it would appear that the action of the left ventricle has ceased, appears sufficient to cause the blood to flow to the most dependant part: And hence, for the aorta, situated nearly in the centre of the body, through either the anterior, the lateral, or the posterior branches, given off from that trunk or from other trunks, to be presented to the mouths of the most superior capillary vessels; which probably remaining some time after apparent death, they are enabled by their own action to propel on the blood into the venous system, causing the engorgement of the veins, and the lividity of

the arteries that is met with after death.

By the force of gravity combined with the valves of the system we are unable to explain the phenomena that took place in Magendie's experiment before related and in that made by myself. Since the impulse of the heart was cut off in the one case by pressure, in the other by a ligature on the artery, yet the circulation went on in the veins till the arteries were entirely empty.

[illegible] death from lightning [illegible] contradicts the above opinion. For here vitality is destroyed in every part of the system at the same instant; the action of the capillaries ceases simultaneously with that of the heart; hence the blood that was contained in the arteries at the moment of death, must remain there; as it is found to be the case, excepting what passes into the various tissues.

What has been said above [illegible]

view of the subject. It might be considered necessary next to inquire, into the blood or chyle passing through the lungs into the pulmonary veins, thence into the left auricle and ventricle and from thence, return [illegible] of the capillary vessels: and thus keeping up an unimpeded circulation till exhausted [illegible] and action in the capillary vessels was expended.

But this part of the subject has in the 13th no. of the Journal of Foreign Medical Science in a paper by [illegible] been so satisfactorily explained by reasoning and by experiments, one of which has already been related, and as this is in some measure distinct from the other part of the subject, I shall only mention the conclusion at which he has arrived, namely.

1st. The blood is obstructed in its passage through the lungs, on suspension of respiration,

"while its circulation through other parts of the
"body continues

2nd "The obstruction of the blood in the
"Lungs or suspension of respiration, is not the effect
"of a mechanical cause

3rd. "The obstruction of the blood in the lungs
"or suspension of respiration arises from a depriva-
"tion of pure atmospheric air.

4th. "The blood found "post mortem" in the left
"auricle and ventricle, is the remnant after the
"last systole, and the subsequent draining of
"the pulmonary veins.

5th. "The obstruction of the blood in the Lungs or
"suspension of respiration, is one of the principal
"causes of the scarcity of the systemic circulating
"arterial blood, post-mortem.

6th. "The immediate Cause of the cessation of
"the action of the heart, is a privation of its natu-
"ral stimulus, arising from the obstruction of the blood in
"the Lungs.

From his experiments [illegible] came to conclusions nearly similar to the ones here reported.

Thus in the first division of the subjects we see the capillaries of the [illegible] ready to convey the blood from the [illegible] are unable to the [illegible] [illegible], because it has not acquired a [illegible] the condition and situation which is necessary to affect the external stimulus.

Now in the next division the capillaries of the [illegible] system [illegible] the [illegible] [illegible]. The vessels are completely emptied, because the blood is in a proper state for affecting the external stimulus.

It will be perceived that many of the experiments related, have been extracted from the writings of other persons. On this account I consider them worthy of more reliance, as they were performed by persons of far greater experi-

experience in Vivisections than myself, and particularly, as they were not performed with the intention of supporting views herein contained.

To conclude; I shall sum up briefly the opinions I have endeavoured here to maintain

During Life the blood is distributed throughout the arterial system, and presented to the Capillary vessels, chiefly by the contraction of the left ventricle: Yet is assisted by the elasticity and contractility of the arteries.

Its passage back to the heart, again to go the round of the pulmonary circulation, is mainly effected by the action of the capillaries, though more or less assisted by certain collateral powers, as muscular action, the vacuum formed in the chest by inspiration &c.

But after apparent death, Gravity effects partially, what the heart did during Life, it causes the blood contained in the arteries, after the last

contraction of the left ventricle, to flow to the most dependant capillaries, to be by them propelled into the venous system.

Thus on the one hand causing the vacuity of the arteries after death; while on the other, they are prevented from being again filled, by the capillaries of the Lungs refusing to circulate blood not changed by Respiration.